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THE INFERIOR BOUNDARY OF THE QUATERNARY ERA.

By Oscar H. Hershey.

The great diversity of physical conditions of the earth's surface in the Quaternary era of its geological history, has been conducive to much legitimate difference of opinion among students as to the most natural boundaries of the era. A few consider it proper to commence it at the opening of deposition of the now well known Lafayette formation. A few others, the writer included, would date it from the close of the Lafayette epoch of aggradation in the coastal plain and Mississippi embayment regions. But the larger number of geologists are accustomed to refer its beginning only as far back as the first marked extension of land ice in North America and Europe, namely, to the opening of the Kansan epoch. It is the purpose of this paper to defend, if possible, the intermediate proposition.

The Quaternary era, as limited by many geologists, was characterized by a great extension of land ice in the form of broad *névés* passing into and bordered by vast glaciers. As known from their effects, these masses of glacial ice were of great extent, covering at their maximum expansion millions of square miles of the northern temperate zone, and having great development on other parts of the earth's surface, notably in the southern portion of South America, and on nearly all high mountain ranges even under the equator. But between the several maxima of cold, producing and in part produced by these glaciers, there seem to have been climatic periods of comparative mildness. These are commonly known as interglacial epochs because the deposits which belong to them are frequently found terbedded with those which are due to direct ice action, and also because they separated the several epochs whose most characteristic condition was glaciation. But the interglacial epochs were longer than the alternate glacial epochs so that in point of time the Quaternary era, even considered as synonymous with the term, "The Ice Age," did not have glaciation as its predominating condition. In the light of modern discoveries in the later geologic history of Europe and America, the "Glacial period" becomes more figurative than real. Glaciation was the most remarkable and the most prominent feature of the Quaternary era, but its importance was not so great as to overshadow the claims of other natural conditions to the right of constituting the essential elements in the definition and limitation of the era.

It is the opinion of the present writer that the era whose early boundary is under discussion, was naturally set apart from all preceding time by a difference in climate, and to a less marked extent by a difference in fauna and flora; not so much by new species of animals and plants as by a different distribution of them. Just as the present climate differs from that of the Tertiaries so also differed the general Quaternary climate therefrom. We are, in fact, probably living under the normal conditions of the Quaternary era; at least there is no very important difference between the interglacial floral and faunal remains and those of the present time. But all of the various lines of research into the conditions prevalent in the Tertiary era, combine to demonstrate that its climate, in any given geographic district, was somewhat milder than in the same locality at the present time. It is the time of change from the mild Tertiary climate to the somewhat colder Quaternary climate that I would consider as the most natural and, therefore, the most convenient divisional line between the two eras.

In endeavoring to fix this time of climatic transition by means of the effects produced, we are confronted by the imperfection of the geological record. A large part of the interval between the time of pronounced Tertiary mildness and early Quaternary severity, was occupied by conditions not favoring the preservation of organic remains, namely, by an elevated condition of the land and rapid erosion. Hence, we are reduced to the necessity of theoretically deducing the most probable cause of such a general change in climate, and then endeavoring to fix by evidence, if possible, the time when said cause or causes came into operation.

The general climate of any portion of the earth's surface is determined by latitude, i. e., by the amount of heat received from the sun. But there are other influences which combine to modify the climate of any given locality. The most important are the extent and position of the bodies of land, the heighth and trend of mountain ranges, and the relation between ocean and air currents. If all these conditions remain unchanged for a very long period, no great diversity of climate will effect the locality. But any disturbing influence, destroying the relations between the conditions mentioned must, *in rerum naturæ*, effect the climate of the entire earth to a certain extent. Of strictly terrestrial causes there are none so potent to bring about this result as great earth movements, changing the relation between the continents and seas, thus modifying the ocean currents, and by presenting barriers in the form of high mountain ranges, interfering with the courses of the prevailing winds. In view of the fact that astronomical causes of the changes of geologic climates are not capable of practical demonstration, while the terrestrial or land movement theory not only is capable of such proof, but already such evidence has been collected to indicate at least a time relation between the main land disturbances and the most important climatic changes, I shall consider only the latter hypothesis in the present discussion.

If the peninsula of Florida were uplifted several thousand feet into a high narrow plateau, and then dissevered by the erosion of deep valleys into separate mountain peaks and ridges, the present warm temperate and subtropical flora and fauna would largely disappear. With the production of a rocky sea-cliff about its borders and the destruction of the swamps and marshes, the palmetto and alligator, each the most characteristic portion of the Floridian flora and fauna, would be eliminated; forced to migrate or become extinct. With them would go the destruction of many other animals and plants. The geologist who would make a study of the region one million years hence, would find such a great contrast in the fossil remains enclosed in the strata laid down near the coast now and those after the uplift, that he would be constrained to refer them to separate periods in his geologic classification. Yet the climate and natural history conditions of the rest of the earth's surface may have remained unchanged, so that his divisions, based on the changes in Florida, would be of merely local significance.

But if the uplift, instead of being confined to the peninsula of Florida, were of continental extent, its effects would be far reaching and very important. With the extension of the land area, there would be an increase of the distinctly interior portion of the continent, whose climate, slightly different from that of the coasts, would have an appreciable effect on the flora and land fauna of the present coastal regions. The elevation of the continent, also, would lower the general temperature throughout its extent, driving southward the present north border of various temperate species of trees and other plants, and so changing the facies of the flora in any given locality. Such elevation of a very extensive land area, if thousands of feet in height, would have some effect on the climate of the entire earth, although just what this effect would be would depend largely upon the situation of the uplifted land with relation to the prevailing winds and ocean currents. But the most important manner in which the uplift would effect the natural history of the continent would be through radical changes of its soil and physical features. The low-lying, somewhat swampy plain, with its deep soil resulting from a long accumulation of the products of secular decay, would give place to a sharply dissected plateau, the steep hill sides and narrow crests of its individual ridges covered but thinly with a stony soil. While the effect upon the flora and fauna of any one change in conditions would probably be comparatively slight, the combined effect of all must be considerable, even if the uplift be but little. Indeed, it seems evident that not even the least change in the relation between land and sea can occur without somehow effecting the climate, and through it the life characters of the region in movement.

In an article entitled "The Relation between Baseleveling and Organic Evolution,[1] J. B. Woodworth discusses "the effect, on organisms, of the changes in physical geography which arise in the process of baseleveling." One of his most important conclusions is that the great change at the close of the Mesozoic era, from a characteristically reptilian to an equally characteristic mammalian land fauna, was due primarily to the great change in the physical features of the continent which is known to have closed the Cretaceous and introduced the Eocene period. The low-lying denudation plain of the later Mesozoic era was rapidly changed into the more elevated hilly land surface of the early Tertiary era. Toward the closing stages of Tertiary time, a peneplain had again been formed over a large portion of the continent, but it was not so perfect nor so extended as the previous one, and, hence, its effect upon organic life was less marked.

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[1] American Geologist, Vol. XIV, No. 4, October, 1894.

The main Tertiary or Tennesseean period of base-leveling in the eastern portion of North America was terminated by a slight seaward tilting of the continental plateau. A portion of the former land area was depressed beneath the sea, and on it was laid down a marine formation of red and orange gravelly loam—the Lafayette formation. The land on the alternative side of the axis of general deformation was slightly uplifted, thereby stimulating the streams to greater activity, which carried the products of rock disintegration into the neighboring sea to form the Lafayette formation. The soil and subsoil of the land area of that time were prevailingly of a red color, for had it been otherwise the Lafayette formation would not be so generally of that tint. Red soils are characteristic of lands whose climate is comparatively mild. The soils of the central and upper Mississippi basin, from whence chiefly was derived the red Lafayette loam of the Mississippi embayment region, are not known to have been of a decided reddish tint in the Quaternary era, except locally during the mild Aftonian interglacial epoch. On the contrary, the colors which almost exclusively dominate the deposits and buried soils of the Quaternary era are blue, yellow, brown and black. The fineness of the materials introduced by glaciation, the broad swampy flats, and the usually severe winter climate were the combined causes of the dark color of the Quaternary soils. None of these conditions were present in any marked degree during the Lafayette period, as the color and composition of the marine deposits and interior river gravels positively demonstrate.

The causes which produced glaciation not yet having begun to operate on the continent, the extension of the warm gulf waters to the head of the Mississippi embayment and the borders of the southern Appalachian province, must have introduced a milder climate into the upper and central portions of the Mississippi basin, providing no counteracting influences were brought to bear. The probable slight elevation of the continent northward from the Lafayette coast certainly did not possess sufficient power to modify the climate to any appreciable extent. Therefore, it seems evident that any change of climate in the eastern half of the territory now included in the United States, which may have accompanied the opening and culminating stages of the Lafayette epoch, must have been in the nature of increasing mildness instead of an increase in the severity of the climate. In short, so far as the climate is concerned, all the evidence which is at present known to exist is demonstrative of the practical continuance of Tertiary conditions to the close of the Lafayette epoch. Hence, those geologists who wish to include the Lafayette epoch under the Quaternary era, must base their claims on some other natural feature than climate. Mere earth movement, if its effects are not prominent, cannot be considered as instituting a new era, and, as the elevation of any part of America or the world at large in the Lafayette epoch is not known to have been great in vertical extent, and to have seriously effected climates, it can hardly constitute a legitimate reason for placing the epoch in the Quaternary era.

Immediately following the close of the Lafayette epoch there was a period of pronounced elevation of the continent. This is indicated by the valleys which have been eroded beneath the surface of the Lafayette deposits, by the great depth of the coastal valleys now submerged to form the fiords of the coasts of British America, Alaska, Scotland, Norway, Patagonia and other portions of the earth's land area; and no less truly though less definitely by the cañon valleys of the interior portions of the North American continent. The period of high-level continued to the opening of the Kansan epoch of glaciation, when, through some cause not rightly understood, but probably largely the great weight of the accumulating ice-sheet, the land in the eastern half of North America was depressed, and has remained to the present time at a much lower altitude than before the Kansan epoch. The high-level period or epoch just mentioned, seems naturally set apart both from the preceding low-level Lafayette epoch and the succeeding low-level Glacial epochs. It has, therefore, been defined as a geologic time unit and designated the Ozarkian epoch, from the fact that its results are so well seen in the sharp cut cañon valleys of the Ozark mountain and plateau regions of southern Missouri and northern Arkansas.

Although commonly considered as a unit, the Ozarkian high-level epoch was probably characterized by two main elevatory movements. The first began and ended at and very soon after the opening of the epoch, and was of great areal extent but not very marked vertical movement. To it, however, may be traced nearly all the recognized effects of the Ozarkian high-level condition of eastern North America. The second decided disturbance of the earth's equilibrium seems to have occurred very nearly at the end of the epoch. It was somewhat local in nature and effected most the northeastern portion of America, (and probably all the lands surrounding the North Atlantic). I must acknowledge that I am basing my claims for this elevatory movement on somewhat slender evidence. But the deep, narrow, now submerged valley channels in the border portions of the continental plateau off the mouths of such rivers as the Delaware and Hudson, certainly were not in process of excavation during the whole or even any large part of the Ozarkian epoch. They must be the result of a special elevation near the close of the epoch. And, further, the cañon valleys of the Mississippi basin sometimes have rock shelves buried under the present valley bottom. Often these rock shelves cannot be explained by any inequality of the strata excavated, but seem to indicate a renewed period of uplift near the close of the epoch. I may also add that those who, like the present writer, are inclined to find between the preglacial high-level of the eastern part of North America and the immediately succeeding glaciation a relation somewhat like cause and effect, see nothing at all improbable in the idea of a marked, comparatively rapid, local uplift of the regions afterwards glaciated.

The Ozarkian epoch, as already indicated, was terminated by the accumulation of the Kansan ice-sheet and the consequent depression of much of the land formerly elevated. It is here that most geologists wish to open a new era in the earth's geological history. There are, I believe, a number of objections to it. In the first place, glaciation, although effecting millions of square miles, was yet local when the entire land area of the globe is taken into consideration. Beyond the districts actually glaciated, it is often very difficult to accurately locate in a series of "effects" those which are chronologic equivalents of the opening of the Kansan epoch. A marked elevation of wide extent would, by reason of its having an observable effect on the streams of the disturbed area, and thereby modifying to a certain extent the erosion forms produced, be of vastly more utility in establishing a natural classification of time than a local accumulation of land ice. Furthermore, we have no evidence of any great change in climate, and hence in flora and fauna in the unglaciated districts at the opening of the Kansan epoch. Certainly the temperate species of animals and plants were driven away from the near vicinity of the ice, but to what distance we cannot say. Indeed, there is no probability that the change in the natural history conditions of regions not close to the great Quaternary glaciers at the opening of the Kansan epoch, was nearly as radical as that which must have resulted upon the withdrawal of the sea to beyond the present coasts and the general continental uplift and peneplain dissection which characterized the early stages of the Ozarkian epoch. If change of climate, of the physical features of continents, and of the geographic distribution of faunas and floras be accepted as the prime essentials in establishing a new era, the opening of the Ozarkian epoch has superior claims over the opening of the Kansan epoch.

The great geological eras are demarked by widespread unconformities and a radical change in sediment. As every effect has had a cause adequate to produce it, it may be assumed that these breaks in the sedimentary series were correlated with and directly dependent upon great changes of the land areas, usually of continental and often of almost worldwide extent. These changes were of the nature of great earth pulsations, uplifting and depressing the continental plateaux, and, when the contraction of the earth's crust was very severe, corrugating it and even, at times, fracturing it along certain lines of weakness. The new geological era thus instituted is usually considered to date from the time that the disturbance first assumed prominence, modifying the flora and fauna of the land areas and the nature of the sediment deposited in the sea about their borders. In short, it may be considered a rule that the natural opening event of the eras previous to the Quaternary as at present constituted, was a profound disturbance of the earth's equilibrium, and it does not seem to the writer that this rule should be set aside in subdividing the later geological history. Therefore, convenience and the need of a classification based strictly upon natural conditions, seem to demand that the Ozarkian epoch should be included under the term Quaternary era.

If we accept the above proposed innovation on the generally accepted scheme of geologic time divisions, we are constrained to reconstruct the previously established Quaternary classification. For it will soon become evident that the time of Ozarkian high-level of the continent deserves more than a mere recognition as an epoch equivalent in significance to any one of the succeeding glacial or interglacial epochs. It was pre-eminently a time of comparatively elevated conditions of the land *without glaciation.* Succeeding it was a period characterized by alternating glacial and non-glacial conditions, rapid epeirogenic movements, repeated migrations of faunas and floras, but no long continued high-level conditions. In point of time the former or Ozarkian period or epoch was by far the longer. This is graphically illustrated by the vast difference in the amount of valley erosion accomplished during the two periods. Although the glacial epochs are usually considered to have been accompanied by increased precipitation and other favorable conditions for rapid erosion, the valleys then excavated are quite insignificant as compared with the Ozarkian valleys. More erosion was accomplished in certain districts during the Aftonian interglacial epoch than during the combined Kansan, Iowa, Toronton ? and Wisconsin epochs. Yet the Aftonian rock gorges never approach in size the Ozarkian valleys of the same region. In fact, any one who has studied the Ozarkian valleys of the southern Appalachian, the Ozark and the upper Mississippi regions, and compared them with the results of post-Kansan erosion in such districts as western Illinois and northern Missouri cannot fail to be impressed with the fact that the time which has elapsed between

Quaternary Era	Recent Period		Modern Epoch—Flood plain deposition.
			Terrace Epoch—Valley erosion.
	Pleistocene Period	Glacial division	Wisconsin Epoch—Drift deposition.
			Toronton ? Epoch—Valley erosion.
			Iowan Epoch—Drift deposition.
			Aftonian Epoch—Valley erosion.
			Kansan Epoch—Drift deposition.
		Ozarkian division	Ozarkian Epoch—Valley erosion.

the close of the Lafayette epoch and the opening of the Kansan epoch was longer than all the time since. If we do not adopt any very large factor of safety, the known evidence will imply a length of time for the Ozarkian period twice and, perhaps, thrice as great as all subsequent time. Therefore, by reason of its length and other features in some respects peculiar to it, the Ozarkian period, or more properly sub-period, may be considered co-ordinate with the Glacial sub-period, the two to constitute approximately equal divisions of the Pleistocene period as in the table on page 113.

THE POCKET, OR POUCHED GOPHER.

(*Geomys bursarius.*)

By Clement L. Webster.[1]

In passing over the beautiful prairies of the west, especially in portions of Iowa and southern Minnesota, the attention of the traveler is arrested by the great number of isolated or grouped mounds, which are seen over the surface.

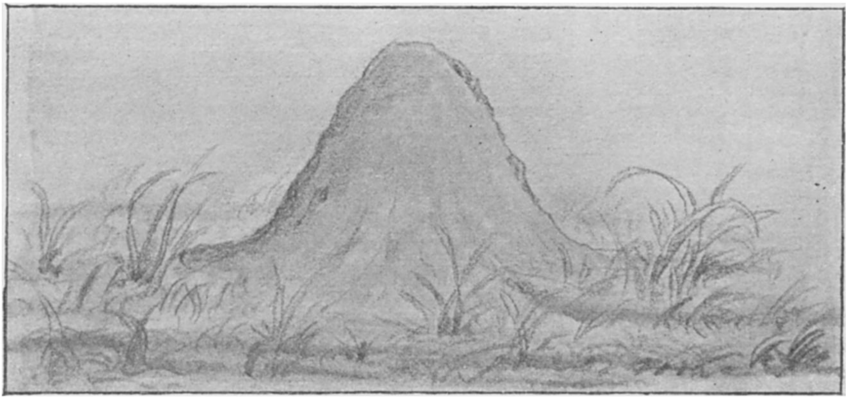

Fig. 1. Geomys bursarius.

These mounds are generally circular, and have a rounded or flattened top; and a diameter, at the base, of from four to twenty feet; and usually rise to a height of from one to three feet.

[1] Charles City, Iowa.